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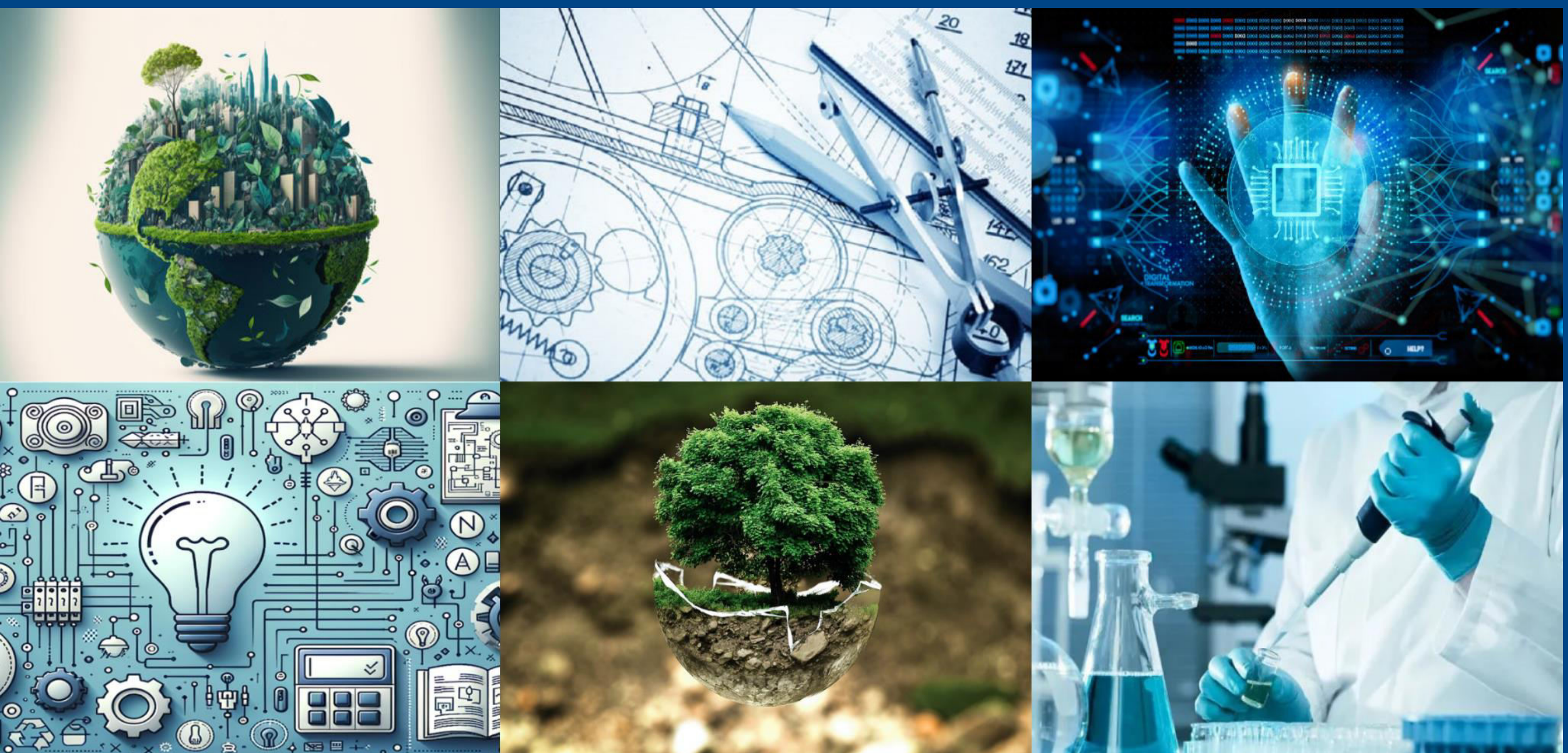

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Smart Agriculture Tech using Internet of Things

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ABSTRACT: A fast-developing multidisciplinary field, smart agriculture, also known as precision farming, incorporates expertise from a variety of fields, including environmental science, data science, technology, and agriculture. Given the abundance of recent research publications on intelligent farming methods and smart agriculture, it becomes necessary to compile their findings into a single consolidated review article. To help stakeholders make well-informed decisions about technology adoption and investment, this work aims to provide an overview of the most important smart agriculture technologies and applications of late, outline the common obstacles it faces, highlight its publicly available datasets for adoption, and provide some policy guidelines. We conclude that the agricultural industry could undergo a revolution thanks to smart agriculture.

KEYWORDS: Smart sensors, smart agriculture applications, precision agriculture, agricultural technology, agricultural datasets, IoT in agriculture, smart agriculture, and agricultural success stories.

I. INTRODUCTION

Using cutting-edge technologies to boost production, sustainability, and efficiency, smart agriculture (SA) is proving to be a paradigm shift in contemporary farming practices [1]. Fundamentally, SA incorporates a wide range of technology elements, beginning with the installation of sensors and Internet of Things (IoT) gadgets. Key tenets of SA's operations include resource optimization, data-driven decision-making, sustainability, precision and accuracy in agricultural methods, and integration with market access platforms [2]. Crop growth, crop monitoring, livestock management, irrigation management, disease and pest control, supply chain optimization, and farm management systems are some of the main application areas of SA.

II. RELATED WORKS

Through the strategic use of data, cutting-edge technologies, and real-time information in agriculture management, PA aims to increase crop yields, reduce resource waste, and improve overall efficiency. GPS technology, satellite imaging, and sensors are essential components for gathering comprehensive data on crop health, weather patterns, and soil conditions. This data is then processed using machine learning and data analytics algorithms to generate useful insights. While automated machinery and robotic systems are used for precise tasks like planting, harvesting, monitoring, and maintenance, the primary goal is to precisely customize inputs like water, fertilizers, and pesticides to meet the specific needs of each field section, minimizing waste and optimizing resource ..

A. INTERNET OF THINGS DEVICES

A physical object that is networked and equipped with sensors, actuators, and software to collect, share, and utilize data is known as an Internet of Things (IoT) device [30]. These gadgets, which can range from commonplace items to specialist gear, are made to improve automation, communication, and data-driven decision-Because IoT devices collect data in real time on a variety of topics, including soil moisture and animal behavior, they are crucial to the advancement of smart farming. Farmers can monitor and control their operations remotely thanks to the internet transmission of this information [12]. IoT helps enterprises with energy optimization, inventory tracking, and predictive maintenance.

In addition to covering their many uses, Reference [32] explores the latest advancements in IoT and sensor technology for agriculture. Crop disease detection, irrigation monitoring, fertilizer administration, processing, logistics, harvesting, forecasting, climate monitoring, and fire safety are among the main applications. It also offers a range of sensors that can detect different plant illnesses, livestock, flexibility wearables, temperature, humidity, light, CO2, electrical conductivity, moisture, nitrate, pH, and weather stations. Some IoT applications in SA are depicted in Figure 3.

III.PROPOSED BLOCKCHAIN AND IOT BASED SOLUTION FOR SMART AGRITECH

This section describes a complete Smart Agri Tech system that uses IoT for real-time data collecting and monitoring and blockchain for safe data management. The system architecture is shown in Figure 2, emphasizing how blockchain smart contracts and Internet of Things sensors are combined to improve agricultural decision-making, automation, and transparency.

Two smart contracts—the Supply Chain Contract and the Farm Monitoring Contract—power the system. Together with IoT devices, these contracts automate vital tasks including resource utilization, crop health tracking, environmental monitoring, logistics, and payments. Only authorized stakeholders are given access privileges through a decentralized application (dApp) connected by an application programming interface (API).

A. PRIVATE PERMISSIONED ETHEREUM NETWORK

To secure sensitive agricultural and supply chain data, our system operates on a private permissioned Ethereum blockchain. This allows data generated by IoT devices—such as soil moisture, temperature, humidity, pH, and pesticide levels—to be shared only with authorized participants, ensuring privacy, security, and integrity.

Using a permissioned network improves scalability and compliance while enabling interoperability with government agencies, agri-tech platforms, and food certification authorities.

B. BLOCKCHAIN INTEGRATION

The solution's main component is the integration of IoT devices with blockchain. IoT sensors placed throughout farms and transportation units gather real-time environmental and logistics data, which is then securely sent to smart contracts that automatically validate and log the information on-chain, causing events like alerts, recommendations, or payments. These contracts are created using the Remix IDE and first tested on a JavaScript-based Virtual Machine (VM) to mimic and confirm behavior before being deployed on the private Ethereum network. The system guarantees: Secure transactions for input/output tracking and payment disbursement; Immutable records of environmental data for traceability; Automated decisions based on sensor thresholds (e.g., irrigation scheduling, pest control, etc.).

C. PARTICIPANTS INTERACTIONS

Three steps of the interaction flow between system members are depicted in Figure 3:

Phase 1: Sensor Deployment and Environmental Monitoring: To continuously collect data on weather, temperature, and soil moisture, IoT sensors are placed on farms. The Farm Monitoring Contract automatically incorporates this data. Through the dApp, farmers and agronomists may view this data and get real-time recommendations. .

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Phase 2: Crop Growth and Intelligent Alerts: Incoming sensor data is analyzed by smart contracts. The farmer receives automated alerts whenever predetermined criteria are crossed (such as low soil moisture). For auditing and analysis purposes, the system records interventions (such as watering and spraying) and keeps the data permanently on-chain.

Phase 3: Once crops are harvested, smart contracts record harvest metadata and initiate logistics tracking. IoT devices installed in transport vehicles monitor temperature, humidity, and GPS location. When delivery is confirmed, the smart contract verifies the conditions and automatically processes payments to stakeholders, reducing delays and intermediaries.

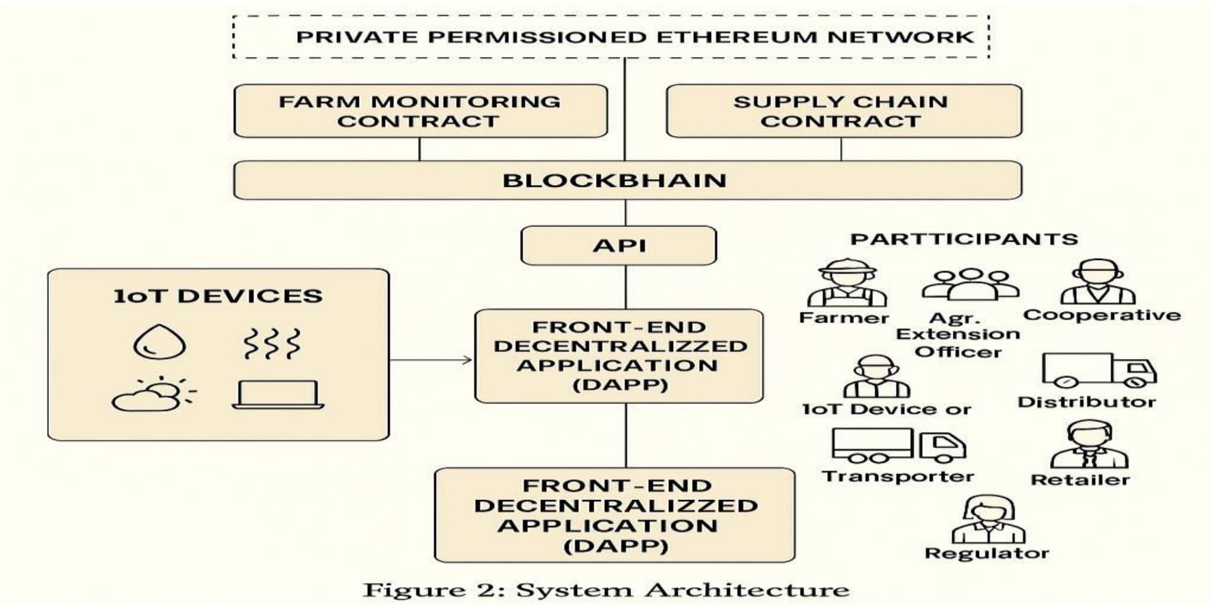

FIGURE 2: A high-level system architecture of the suggested blockchain-based solution For Smart Agriculture

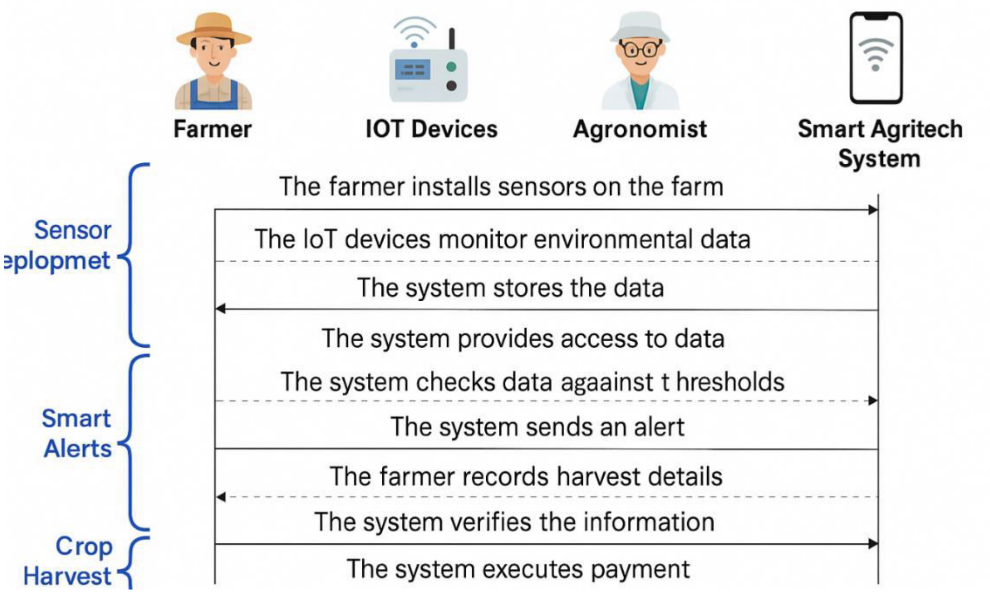

Figure 3: A flowchart illustrating the participants' and the IOT based smart agritech system interact

IV.IMPLEMENTATION DETAILS

The Smart Agriculture system is built using Internet of Things **(IoT)** devices, enabling real-time monitoring, automation, and data-driven decisions to optimize agricultural processes. The architecture of this system follows a four-layer model, inspired by modern IoT solutions for efficient agricultural management.

A. System Architecture

The system is divided into four core layers:

A. Perception Layer (Data Collection & Sensors)

- In Smart Agriculture: Sensors placed throughout the farm collect real-time data on various environmental factors that affect plant growth. These sensors are akin to "smart" devices and are often connected to edge computing devices for initial processing.
- IoT Devices Used:
- o Soil moisture sensors: Measure the water content in the soil.
- o Temperature and humidity sensors: Monitor the environment's air quality.
- o Light sensors: Measure sunlight exposure.
- o Crop health sensors: Detect leaf temperature, chlorophyll levels, or plant diseases.
- o Weather stations: Collect data on temperature, rainfall, and humidity for accurate weather predictions.
- Entities:
  - o Farmers use mobile apps or cloud-based dashboards to monitor sensor data and adjust farming practices accordingly.

B. Network Layer (Communication & Data Transfer)

- In Smart Agriculture: The data collected by sensors needs to be transmitted securely and efficiently to a central processing system. This layer ensures that all devices are connected and can communicate with each other through various network technologies.
- Technologies:
- o Wi-Fi / LoRaWAN / ZigBee / Cellular networks for data transfer
- o IoT Gateways: Devices that aggregate data from sensors before transmitting it to the cloud or local servers.
- o Edge devices: Local servers or embedded systems that preprocess data, reducing the amount of data that needs to be sent to the cloud.
- Data Flow:
- o Sensor data is transmitted from the Perception Layer to a central server via wireless networks or IoT gateways. Edge devices may filter or preprocess the data before it reaches the cloud, reducing latency.

C. Processing Layer (Data Analysis & Decision-Making)

- In Smart Agriculture: This layer handles the data analysis, using machine learning algorithms, data analytics, and cloud computing to turn raw data into actionable insights for farmers.
- Key Operations:
- o Data aggregation: Collects data from multiple IoT devices (soil sensors, weather stations, etc.).
- o Data analysis: Cloud-based platforms process this data, detecting trends, anomalies, and correlations.
- o Predictive analytics: Uses historical data, weather predictions, and soil conditions to forecast crop yields, water needs, and pest outbreaks.
- o Automation triggers: Based on the analysis, the system may automatically activate irrigation systems, adjust lighting in greenhouses, or trigger pest control systems.
- Technologies:
- o Cloud platforms (AWS, Google Cloud, Microsoft Azure)
- o AI & ML algorithms for forecasting, anomaly detection, and optimization.
- o Big data analytics tools for processing large-scale data sets (e.g., Apache Hadoop, Spark).

D. Application Layer (User Interface & Control)

- In Smart Agriculture: The application layer provides the user interface (UI) for farmers, agronomists, and stakeholders to interact with the system. This layer includes mobile apps, dashboards, and alert systems that display processed data and insights.
- Core Features:
  - Real-time monitoring: Dashboards display data such as soil moisture levels, temperature, humidity, and crop health status.
  - Alerts & Notifications: Farmers receive real-time alerts about critical conditions, such as low soil moisture, pest infestations, or weather events.
  - Automated control: Based on the collected data, farmers can automate processes like irrigation, fertilization, or pest control.
  - Data visualization: Graphs and charts display trends like weather conditions, crop health, and resource usage over time.
- Interfaces:
  - Mobile apps: For easy, on-the-go monitoring and management.

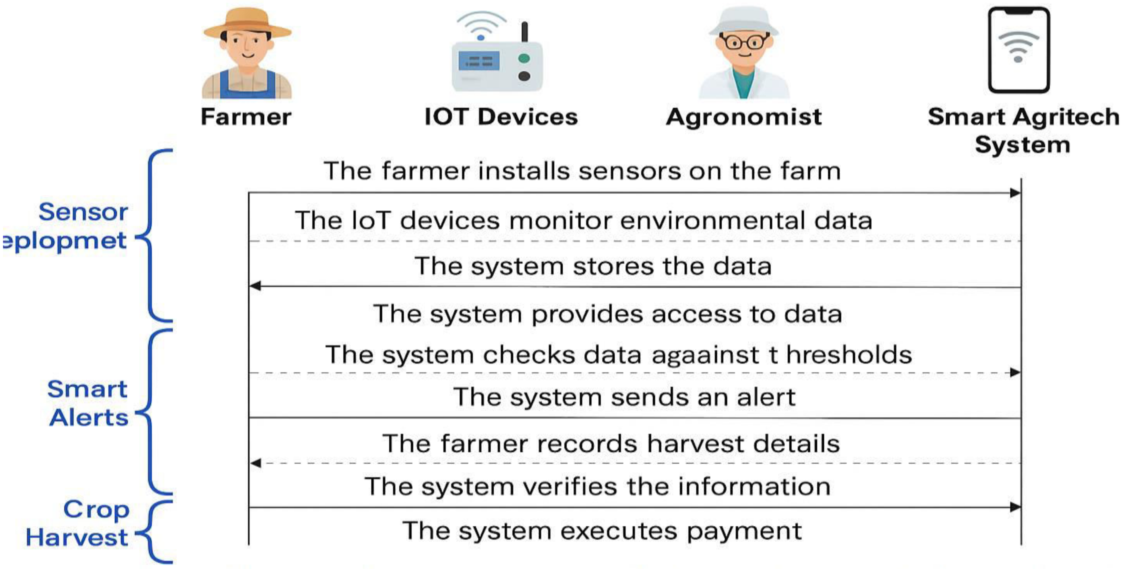

Figure 4: A flowhart illustrating how the participants and the IoT-based smart agritech system interact

Figure 4: A flowchart illustrating how the participants and the IoT-based smart agritech system interact.

The entity-relationship diagram that illustrates the core features and capabilities of the smart contracts in our proposed Smart AgriTech system is shown in Figure 5. The system consists of two main contracts: the Farm Monitoring smart contract and the Supply Chain smart contract. The Farm Manager is defined as a single Ethereum address, as there is only one responsible manager for each farm. Multiple entities, including farmers, IoT sensors, and farm fields, are defined using mappings due to their plural existence in the system. Farmers are represented with unique IDs and addresses, and each farmer manages one or more farm fields. These fields include details such as crop type, area, and soil condition. Sensors are deployed across fields and are categorized by types—such as temperature, humidity, soil moisture, and pH sensors—using enumerates. Sensor data is recorded automatically and linked with timestamps to ensure data traceability. In addition, entities like distributors and retailers are also represented as address mappings, reflecting their roles in the post-harvest supply chain. Enumerates are used to specify various crop types and sensor categories to standardize data handling. The primary functions of the smart contracts include registering new farmers, deploying and linking sensors to specific fields, recording sensor readings, generating automated alerts based on thresholds, logging harvest details, tracking product movement through the supply chain, confirming delivery, and handling payments securely.

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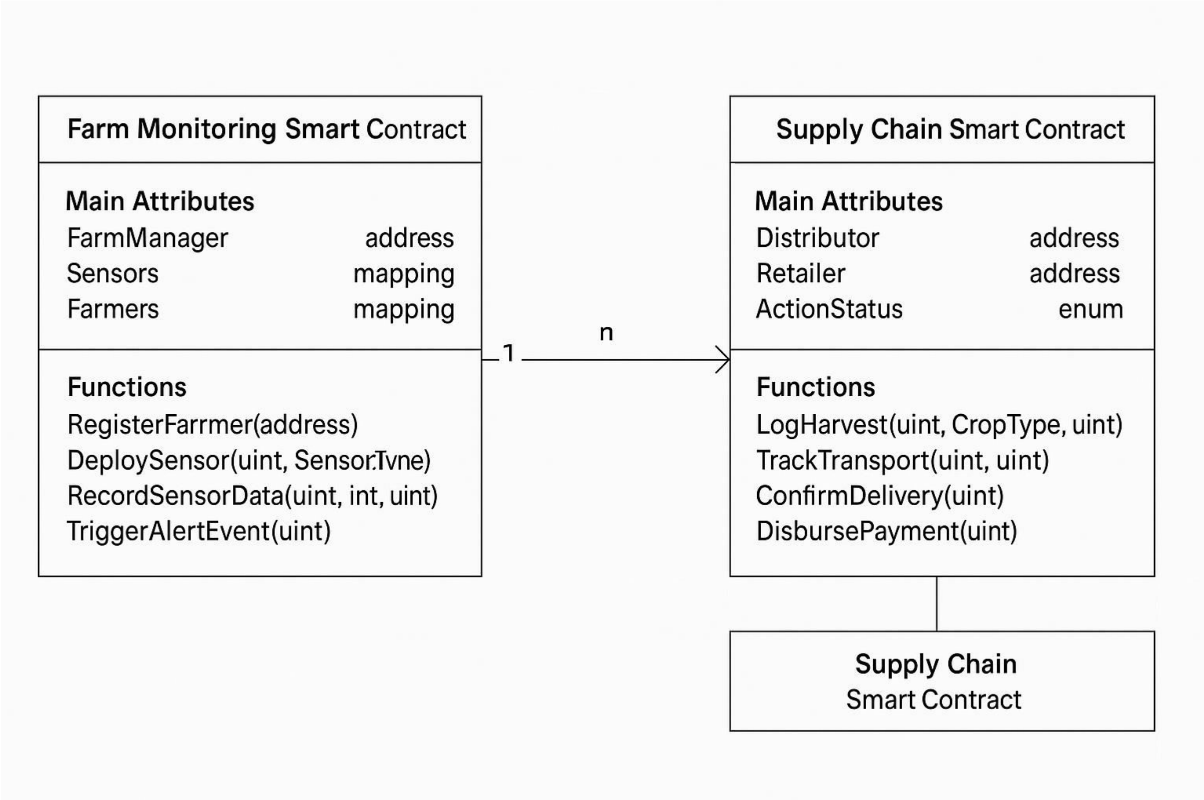

Figure 5: Entity-relationship diagram for smart agriculture

The smart agritech system leverages IoT sensors, the Random Forest machine learning algorithm, and the Backtracking algorithm to optimize crop monitoring and resource management. Algorithm 1 initiates with the Register Farm Plot and Assign Sensor Nodes functions, wherein farm plots are equipped with IoT devices that continuously monitor environmental factors such as temperature, soil moisture, humidity, and light intensity. These real-time readings are stored on a secure blockchain and form the input dataset for further processing. In Algorithm 2, the system uses the Random Forest algorithm to analyze historical sensor data and predict optimal crop types based on soil condition, climate trends, and resource availability. The Predict Crop Type function outputs a ranked list of crops suitable for a given plot, assisting farmers in data-driven decision-making.

Algorithm 1: Data Collection from IoT Devices

Input: SoilMoisture, Temperature, Humidity, LightIntensity

1 **if** *caller* = Farmer **then**

2 ıf seek data collection (condition then = SoilMoisture > threshold, Temperature > threshold, Humidity > threshold, or LightIntensity < threshold4)

3 **else**

4 **store** IoT data in data set **emit** *Data collected*

Algorithm 2: Crop Disease Prediction using Random Forest

Input: SoilMoisture, Temperature, Humidity, LightIntensity

1 SensorData = SoilMoisture, Temperature, Humidity, LightIntensity

2 use Random Forest algorithm prediction: CropDiseasePrediction (Uase SensorData)

3 **if** CropDiseasePrediction = *"Diseased:*

3.1 recommennd an action for identified disease

3 **else**

4 **emitcp** Prediction completed

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```
# Algorithm 3: Smart Crop Monitoring & Irrigation Control
Input: soil_moisture, weather, crop_type, growth_stage

def auto_irrigate(soil_moisture, weather, crop_type, growth_stage):
    # Optimal moisture thresholds (example values)
    MIN_MOISTURE = 30
    MAX_MOISTURE = 80

    if (soil_moisture < MIN_MOISTURE) and (weather == "sunny"):
        activate_irrigation()
        log("Watering: Dry soil in sunny conditions")

    elif (soil_moisture > MAX_MOISTURE) and (weather == "rainy"):
        activate_drainage()
        log("Draining: Waterlogged soil")

    if (growth_stage == "flowering"):
        dispense_fertilizer(nitrogen=20)  # Crop-specific dosage
        log("Added nutrients for flowering stage")
```

```
# Algorithm 4: Smart Pest Control System
Input: pest_type, infestation_level, crop_stage, weather

def pest_response(pest_type, infestation_level, crop_stage, weather):
    # Thresholds
    CRITICAL_INFESTATION = 70  # % coverage
    SAFE_CROP_STAGES = ["mature", "harvest"]  # No pesticide

    if infestation_level >= CRITICAL_INFESTATION:
        alert_farmer(pest_type, location="GPS_COORD")

    if pest_type == "aphids" and crop_stage not in SAFE_CROP_STAGES:
        deploy_biological_control(ladybugs=True)  # Eco-friendly

    elif pest_type == "locusts" and weather == "dry":
        spray_pesticide(organic=True)  # Targeted dose
        drone_scan(repeat_in=24h)  # Follow-up

    update_database(pest_type, action_taken, timestamp)
```

V.TESTING AND VALIDATION

The main features of the developed smart contracts for smart agriculture using IoT and the Random Forest algorithm are tested and verified in this section. The evaluation phase is conducted using the Remix IDE. Table 1 lists the participants, including farmers and agricultural experts, along with the Ethereum addresses used for testing and validation. The input values used for the contract functions are assumed and intended solely for testing purposes, not representing real-time field data. The subsequent sections present the transaction details and event logs associated with the primary operations of the smart contract.

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LE 1. The Ethereum addresses of participant e smart agriculture testing scenario.

Participant Role	Ethereum Address
Farmer	0x1A23B4De701e6A54dC
IoT Sensor Administrator	0x2B45eF9Dd6ACeE03cE 034cEfbRA61C3BEE
Agriculture Data Analyst	0xF5099A48117c7AEF23cF EF231cCeEA61C3EF5
Crop Disease Prediction Expert	0x3C67eED47cBBAFB5D4 E2SD4ER4F739CD61F
Supply Chain Coordinator	0x6E203FDa01Ce93faA4FF 7BB54E2B9BC70DC
Produce Transporter	0x6E2031DE113aD414F025 BD6afab32EBC70D3
Marketplace Regulator	

A. SMART CONTRACT FOR SMART AGRICULTURE

The Add New Sensor Reading function enables the integration of real-time environmental data into the blockchain-based agriculture management system. This feature allows approved IoT devices or registered farm operators to log field-specific sensor data directly to the Ethereum network. The logged data, recorded in the “logs” field, includes details such as Sensor ID "SEN123", timestamp "2025-05-03 10:00", soil moisture of "42%", temperature of "29°C", pH level of "6.8", and crop type "1" (representing wheat). This function not only ensures secure and tamper-proof data storage but also enables subsequent smart contract functions to make autonomous decisions. The sensor ID is successfully stored in a sensor array, which can later be queried, as demonstrated in system dashboards or further actions.has be

VI. DISCUSSION

This section assesses our solution's degree of security, privacy, and confidentiality. Generally, Ethereum-based These outline the expenses related to putting smart contracts into place and running them. Nevertheless, our method uses the private Ethereum blockchain to adjust the price of gas to zero. Therefore, there are no expenses associated. Furthermore, a comparison of our solution with other alternatives already in place is carried out. Lastly, we go over how our solution can be applied to different systems and applications.

SECURITY ANALYSIS

The proposed smart agriculture system integrates IoT with blockchain to ensure data integrity, automation transparency, and system resilience. Sensor readings—such as soil moisture, temperature, and pH levels—are captured and recorded as immutable events on a private Ethereum blockchain. This event-based logging structure guarantees data integrity by ensuring that every environmental input and automated agricultural action (like irrigation or fertilization) can be verified and traced historically. To enforce access control and accountability, the system employs Solidity's modifier feature, which restricts execution of specific smart contract functions to authorized entities such as registered sensors, automated decision engines, or verified farm managers. The decentralized infrastructure of the blockchain guarantees high availability; even in the case of a node failure, the network remains operational and synchronized due to its distributed nature. Furthermore, all transactions on the blockchain require digital signatures generated using the sender's private key, significantly reducing the risk of man-in-the-middle (MITM) attacks and unauthorized data manipulation. To assess the resilience and security of the smart contracts, vulnerability testing was conducted using Oyente,

Smart contracts for the agriculture system—such as those handling environmental data logging, irrigation scheduling, and threshold alerts—have been rigorously tested against known vulnerabilities including reentrancy, denial of service (DoS), unauthorized execution, and timestamp manipulation. The contracts were found to be secure and stable under various operational scenarios. Their design ensures that automated decisions are always verifiable, and any manual intervention is strictly permissioned. As a result, the system upholds both operational trustworthiness and agronomic reliability.

TABLE X. A comparison of smart agriculture solutions with the proposed system

Features	Our Solution	Agri Chain	AgriLedger	IBM Trust
Blockchain Platform	Ethereum	Ethereum	Hyperledger	Hhereun
Smart Contract	Yes	Yes	Yes	No
Mode of Operation	Private	Private	Public	Yes
Tracing	Yes	Yes	Yes	Yes
Real-Time Monitoring	Yes	No	Yes	Yes
Implementation	Yes	Yes	Yes	Yes
DApps	No	Yes	Yes	No

VII. CONCLUSION

In this work, we presented a comprehensive smart agriculture solution that synergistically integrates Internet of Things (IoT) technologies with a private Ethereum blockchain to create a decentralized, secure, and intelligent farming ecosystem. The proposed system addresses critical challenges in agriculture, such as data tampering, lack of traceability, inefficient resource management, and trust deficits among stakeholders.

IoT sensors deployed in the field continuously collect real-time data on soil moisture, temperature, humidity, crop health, and other environmental parameters. This data is automatically recorded on the blockchain via smart contracts, ensuring that it remains immutable, verifiable, and auditable. By using smart contracts, various farming operations—such as irrigation scheduling, pest control, and supply chain tracking—can be automated, reducing human error and increasing efficiency.

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